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(54) High-dynamics amplifier stage with distortion detection.

(57) In an amplifier stage comprising a pair of input current sources (I_1, I_2), connected in series between a pair of reference potential lines ($+V_{cc}$, $-V_{cc}$), a pair of output transistors (Q_5, Q_6), connected between the pair of reference potential lines and defining an intermediate output terminal (D) of the amplifier, a driving circuit (Q_1-Q_4, Q_7, R_1) comprising active elements and interposed between the input current source and the output transistors, and at least one saturation control circuit (Q_A, Q_B, R_A, R_B) comprising at least one control transistor (Q_A; Q_B) connected with its base to the driving circuit and with its collector and emitter between the output (D) of the amplifier stage and the intermediate point (A) between the input current sources, to detect distortion due to clipping, at least one distortion detection transistor (Q'_A; Q'_B) is provided, connected to the control transistor (Q_A; Q_B) so as to detect the current flowing through the latter, which current is related to the imbalance of the input current sources and therefore to the distortion generated in the stage.

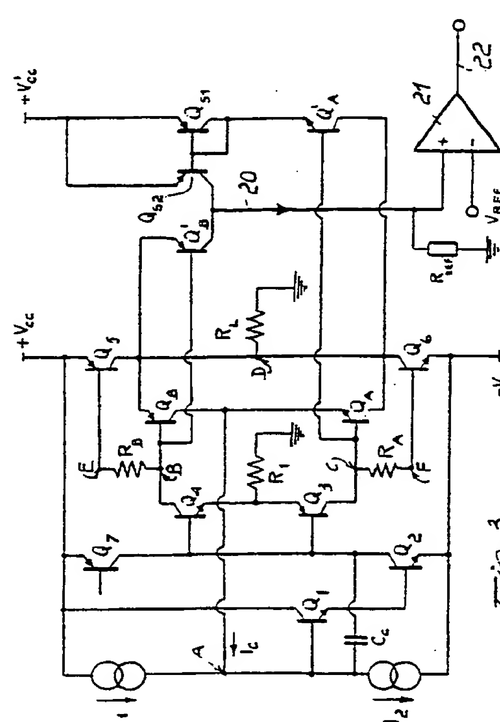

Fig.3

HIGH-DYNAMICS AMPLIFIER STAGE WITH DISTORTION DETECTION

The present invention relates to a high-dynamics amplifier stage with distortion detection, in particular a final amplifier stage with collector output and high dynamics.

In a low frequency amplifier stage of the indicated type, shown by way of example and in simplified form in figure 1, the maximum output voltage is limited in theory by the supply voltage. Actually, in the best of hypotheses, the maximum excursion of the output voltage is equal to:

$2\ V_{CC} - V_{CEQ5,sat} - V_{CEQ6,sat}$

When a low frequency amplifier driving a loudspeaker with a for example musical signal reaches maximum excursion several times, it introduces a distortion due to clipping, so that the resulting sound becomes unpleasant.

A circuit can therefore be conceived which perceives this distortion condition, and sends this information, possibly filtered by means of an appropriate time constant such as to not introduce further distortions, to an attenuator circuit having the function of reducing the signal sent to the input of the amplifier so as to avoid, in stationary conditions, distortions of the output signal due to clipping higher than a given percentage.

For this purpose a circuit connected to the inputs of the amplifier stage has already been studied which can be schematically represented as an operational amplifier. In fact, as is known, in these types of amplifiers, during normal, linear operation, the voltage between the inputs is ideally nil, but becomes different from zero when the output is incapable of proportionally following the input, since the maximum possible output voltage has been reached (i.e. due to the occurrence of clipping). According to this known solution, therefore, the detector is connected to the inputs of the amplifier so as to detect any imbalances thereof indicative of the distortion. For this purpose, the known detector comprises at least two threshold amplifiers or comparators and an adder circuit.

Said known solution, though it indeed allows the detection of clipping, is however not free from disadvantages both due to the high circuital complexity and due to the interaction with the inputs which may be harmful in view, for example, of the decrease of the input impedance of the amplifier stage and of the increase of the input bias current.

Accordingly, the aim of the present invention is to provide a system for detecting the distortion due to clipping in high-dynamics amplifier stage of the indicated type, capable of eliminating the disadvantages featured by the prior art.

Within this aim, a particular object of the present invention is to provide a simple distortion detection circuit, easily integratable with said amplifier stage and such as not to require a substantial increase in the complexity of said amplifier.

Still another object of the present invention is to provide a distortion detector which does not modify the electric characteristics of the associated amplifier stage, in particular as to the input impedance and the input bias current.

Still another object of the present invention is to provide a distortion detector in an amplifier stage of the indicated type, operating reliably and capable of always assuring detection of the presence of distortions.

Not least object of the present invention is to provide a distortion detector integratable in an amplifier stage of the indicated type so as not to entail an increase in costs in the production of the latter.

The indicated aim, the mentioned objects and others which will become apparent hereinafter are achieved by a high-dynamics amplifier stage with distortion detection, as defined in the accompanying claims.

The characteristics and advantages of the invention will become apparent from the description of a preferred but non exclusive embodiment, illustrated only by way of non-limitative example in the accompanying drawings, wherein:

figure 1 is a simplified diagram of the final stage of a known amplifier;

figure 2 is a simplified block diagram of the entire loop for the reduction of distortion due to clipping according to the invention, and

figure 3 is a simplified electric diagram of an amplifier stage according to the invention.

With reference to figure 1, a known low-frequency amplifier stage with low drop-out (i.e. high dynamics) comprises a pair of input current sources I_1, I_2, connected in series between a pair of reference potential lines $+V_{cc}$, $-V_{cc}$ and defining the input stage, generally formed by a voltage/current converter stage. The transistors Q_1-Q_4 and the constant current source Q_7, together with the resistor R_1, represent the driving circuit, while the transistors Q_5 and Q_6 form the two final transistors connected between the lines $+V_{cc}$, $-V_{cc}$ and defining therebetween, at point D, the output of the amplifier which is connected to a load R_L.

As mentioned, said known circuit has a maximum dynamics equal to:

$2\ V_{CC} - V_{CEQ5,sat} - V_{CEQ6,sat}$

so that when the output signal reaches its maximum excursion the already described clipping occurs.

According to the invention, to eliminate the distortion due to said clipping, the diagram of fig-

ure 2 is used, wherein 1 schematically indicates a final amplifier stage of the indicated type. As can be seen in the figure, the output of the amplifier 1, indicated at OUT and driving a loudspeaker 2, is sent to a clipping detection circuit 3 generating a signal proportional to the detected distortion. This clipping signal, through a suitable delay circuit 4, exemplified here by the capacitor 5 and by the resistor 6, is sent to a voltage-controlled attenuator 7 connected ahead of the amplifier 1 and precisely between the input 8 of the useful signal and the input 9 of the amplifier 1. Said attenuator 7, according to the distortion condition detected by the detector 3, reduces the signal sent at the input of the amplifier, thus reducing said distortion.

The distortion detector proposed with the present invention is shown in Figure 3, illustrating a general circuit diagram of the amplifier stage complete with the detection circuit.

An amplifier circuit shown in figure 3 employs the solution object of the published Italian patent application No. 20 195 A/87 filed on April 21, 1987 in the name of the same applicant and included herein as reference, capable of reducing the high saturation of output transistors.

As can be seen in figure 3, the shown amplifier stage still comprises two input current sources I_1 and I_2 and a driving part including transistors Q_1-Q_4 and Q_7 (forming a constant current source) for driving two output transistors Q_5 and Q_6 connected between the positive and negative power supply or reference potential lines $+V_{cc}$, $-V_{cc}$. The two output transistors are mutually connected with their collectors at point D which represents the output of the stage, for feeding the load, represented herein by the resistor R_L.

As in the abovementioned patent application, between the outputs of the driving stage, constituted by the collectors of the transistors Q_4 and Q_3 (points B and C), and the bases of the respective output transistors Q_5 and Q_6, saturation control circuits are connected, constituted by a respective resistor R_B and R_A, connected each between a driving output and the respective output transistor, and by a transistor Q_B and Q_A, having each its base connected to the respective driving output and connected with its emitter and collector terminals between the output D of the amplifier stage and the input A thereof, defined as intermediate point between the current sources I_1 and I_2.

According to the invention, this known circuit is connected a distortion detection circuit essentially comprising a pair of transistors Q'_A and Q'_B connected each to a transistor of the control circuit so as to be flown by the same current. In detail, the base of the transistor Q'_A is connected to the base of the transistor Q_A, while its collector is connected to the collector of Q_A. Accordingly Q'_A has a base-collector voltage equal to that of Q_A and, since the latter is made to operate in its inverse linear region, Q'_A also operates in its inverse linear region and supplies an emitter current, flowing from the emitter towards the collector, equal to the current flowing through Q_A.

Similarly, the transistor Q'_B has its base connected to the base of Q_B and its emitter connected to the emitter of Q_B. Accordingly the transistors Q_B and Q'_B operate with the same base-emitter voltage and therefore have an equal collector current.

In the example shown in Figure 3, the clipping detector circuit, which in its basic structure essentially comprises only one of the transistors Q'_A, Q'_B, here also includes an adder circuit constituted by the transistors Q_{S1} and Q_{S2}. In detail, the transistor Q_{S1} is diode-connected in series between a further reference voltage line V'_{cc} and Q'_A, so as to be flown by the same current as Q'_A, while the transistor Q_{S2}, forming a mirror with Q_{S1}, and therefore flown by the same current as the latter and thus as Q'_A, has its collector coupled to the collector of Q'_B, so that the current flowing in the line 20, connected to the collectors of Q'_B and Q_{S2}, is the sum of the currents detected by Q'_A and Q'_B. In the illustrated example, downstream of the adder circuit a threshold comparator is provided for supplying a control signal only when the distortion detected at the output of the amplifier stage exceeds a given value. For this purpose, the line 20 is connected to the positive input of a threshold amplifier or comparator 21 which receives on said input, by virtue of the resistor R_{REF}, a voltage proportional to the existing distortion. By applying a reference voltage V_{REF} to the negative input of the comparator 21, the latter generates at the output a control signal indicative of minimal distortion, which signal can thus be fed to the attenuator 7, according to the diagram of figure 2, which correspondingly attenuates the signal fed at the input of the amplifier 1 by acting on the sources I_1 and I_2.

The operation of the amplifier with distortion detection circuit according to the invention is as follows.

As already indicated in the abovementioned patent application, initially supposing that the current delivered by the source I_1 is smaller than the current delivered by the source I_2 (i.e. that $I_1 < I_2$) the transistors Q_1, Q_2, Q_3, Q_6 are off, while the transistors Q_4 and Q_5 are on. Accordingly, the voltage of the output point D tends to rise to the positive supply voltage V_{cc}. Accordingly the voltage between the base and emitter of the transistor Q_B also rises and, when it reaches the switch-on threshold thereof causes the switching on of Q_B which thus conducts current between its emitter and its collector. This collector current of Q_B, fed to the input point A, feeds the base of Q_1, preventing

its complete switching off. In practice, ignoring the base current of Q_1, the current through Q_B is practically equal to the imbalance between I_1 and I_2, that is:

$I_c = I_2 - I_1$

If instead the current delivered by the source I_1 is greater than the current delivered by the source I_2, i.e. if $I_1 > I_2$, the excess current of the source I_1 tends to saturate the transistor Q_2 and the transistor Q_6, making the output D approach the negative power supply. Here, too, when the voltage difference between point C and point D reaches approximately 0.6 V, directly biasing the base-collector junction of the transistor Q_A, the same switches on with inverse bias, conducting current between its emitter and its collector. In this case, I_c is given by:

$I_c = I_1 - I_2$

Consequently, due to the connection of the distortion detection transistors Q'_A and Q'_B to the related control transistors Q_A and Q_B, these are selectively flown by a current proportional to the imbalance between the currents I_1 and I_2.

In a complete amplifier it can be shown that, within certain limits, and as in any case imaginable, this imbalance is a function of the percentage of distortion produced by the amplifier due in particular to the attainment of the maximum dynamics of the output signal (clipping).

Consequently, the transistors Q'_A and Q'_B supply a current which is a function of the percentage of distortion and can thus be used for driving the attenuator 7 of figure 2.

In the illustrated case, in which the transistors Q'_A and Q'_B are connected by the adder circuit, a signal is obtained on the line 20 which is linked to the distortion alternately detected by Q'_A or by Q'_B, since the output transistors Q_5 and Q_6 operate alternately. The distortion signal present on the line 20 is fed to the threshold comparator 21 which thus generates a driving signal on the output 22 only when the distortion has reached a preset minimum value, adjustable by means of the resistor R_{REF} or of the reference voltage V_{REF}. This driving signal is then filtered by the circuit 4 and sent to the attenuator 7.

As can be seen from the above description, the invention fully achieves the proposed aim and objects. In fact, an amplifier stage has been provided comprising an extremely simple circuit for detecting the distortion due to clipping which, in some cases, may comprise even only one of the two detection transistors Q'_A or Q'_B, which is easily integratable in the structure of the output amplifier without requiring high circuital complexities or greater bulk , and may be manufactured during the same process steps required for the production of the overall amplifier, so that the latter has overall costs equivalent to known amplifiers.

The indicated solution is also advantageous as to its reliability and also in view of the electric characteristics of the amplifier stage, which are practically not modified by the addition of the distortion detection circuit which operates on the final part of said stage, not altering its input characteristics.

The invention thus conceived is susceptible to numerous modifications and variations, all within the scope of the inventive concept. In particular, though a complete diagram with distortion detection on both output transistors and with further downstream circuits for the unification of the information and for comparison has been shown in figure 3, the fact is stressed that, when this is sufficient, it is possible to provide only one of the two distortion detection transistors and to directly control the attenuator according to the signal supplied by said transistor.

Even if it is preferred to provide both distortion detection circuits, the information supplied thereby may be used separately, without providing the above described unification circuit, or it is also possible to provide a circuit which unifies the information supplied by the two distortion detection circuits which operates differently from the one shown in figure 3.

The fact is furthermore stressed than the threshold comparator may even be omitted and that the obtained distortion signal may possibly undergo further processings, possibly required in particular cases.

Finally, all the details may be replaced with other technically equivalent ones.

Where technical features mentioned in any claim are followed by reference signs, those reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly, such reference signs do not have any limiting effect on the scope of each element identified by way of example by such reference signs.

Claims

1. A high-dynamics amplifier stage with distortion detection, comprising a pair of input current sources (I_1,I_2), connected in series between a pair of reference potential lines ($+V_{cc}$, $-V_{cc}$), a pair of output transistors (Q_5, Q_6), connected between said pair of reference potential lines and defining therebetween an output terminal (D) of said amplifier stage, a driving circuit (Q_1-Q_4, Q_7, R_1) including active elements and interposed between said input current sources and said output transistors, and at least one saturation control circuit (R_A, R_B, Q_A, Q_B)

including at least one control transistor (Q_A, Q_B) connected with its base terminal to said driving circuit and with its collector and emitter terminals between one of said output transistors (Q_6, Q_5) and the input current sources, characterized by at least one distortion detection transistor (Q'_A, Q'_B) connected to said control transistor (Q_A, Q_B) so as to supply a distortion detection current proportional to the current flowing through said control transistor and correlated to the distortion generated by said amplifier stage.

2. A high-dynamics amplifier stage according to claim 1, comprising a pair of saturation control circuits (R_A, R_B, Q_A, Q_B) respectively including at least a first (Q_B) and a second (Q_A) control transistors connected with their base terminals to said driving circuit (Q_1-Q_4, Q_7, R_1), said first control transistor (Q_B) being connected with its emitter terminal to said output terminal (D) and with its collector terminal to said input current sources (I_1, I_2), and said second control transistor (Q_A) being connected with its collector terminal to said output terminal (D) and with its emitter terminal to said input current sources, characterized by a first distortion detection transistor (Q_B) connected with its own base terminal to the base terminal of said first control (Q_B) transistor and with its own emitter terminal to the emitter terminal of said first control transistor and a second distortion detection transistor (Q'_A) connected with its own base terminal to the base terminal of said second control transistor (Q_A) and with its own collector terminal to the collector terminal of said second control transistor, said distortion detection transistors supplying distortion detection currents proportional to the currents flowing through the associated control transistors and correlated to the distortion generated by said stage.

3. An amplifier stage according to claim 1 or 2, characterized in that said distortion detection current or currents is/are sent to a controlled attenuator (7) connected ahead of said amplifier stage (1).

4. An amplifier stage according to any of the preceding claims, characterized by a delay circuit (5,6) arranged between said distortion detection transistor or transistors and said controlled attenuator (7).

5. An amplifier stage according to any of claims 2 to 4, characterized by an adder circuit (Q_{S1}, Q_{S2}) interposed between said distortion detection transistors and said controlled attenuator (7) and having a first input connected to the collector terminal of said first detection transistor (Q'_B) and a second input connected to the emitter terminal of said second detection transistor (Q'_A) for generating at the output a current signal equal to the sum of the currents flowing through said detection transistors.

6. An amplifier stage according to claim 5, characterized in that said adder circuit comprises a current mirror circuit including a first and a second adder transistors (Q_{S1}, Q_{S2}) said first adder transistor (Q_{S1}) having its collector terminal connected to the emitter terminal of said second detection transistor (Q'_A), to its own base terminal and to the base terminal of said second adder transistor (Q_{S2}), said adder transistors having mutually connected emitter terminals and said second adder transistor (Q_{S2}) having its own collector terminal connected to the collector terminal of said first detection transistor (Q'_B) and forming the output of said adder circuit.

7. An amplifier stage according to claims 5 and 6, characterized in that said output of said adder circuit is connected, through a current-voltage converter (R_{REF}), to a first input (+) of a comparator circuit (21) having a second input (-) set to a threshold reference voltage, said comparator circuit generating at the output a control signal when the distortion detected by said detection transistors exceeds said threshold reference voltage.

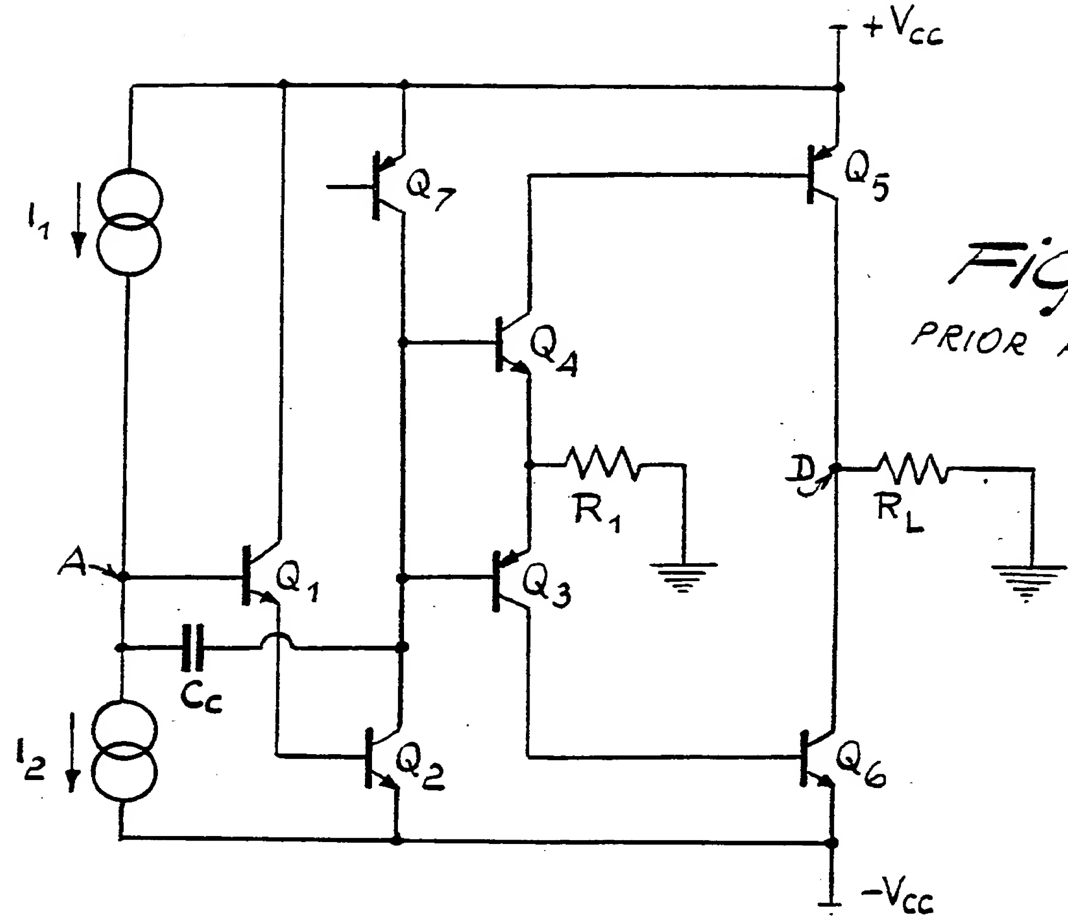

Fig.1
PRIOR ART

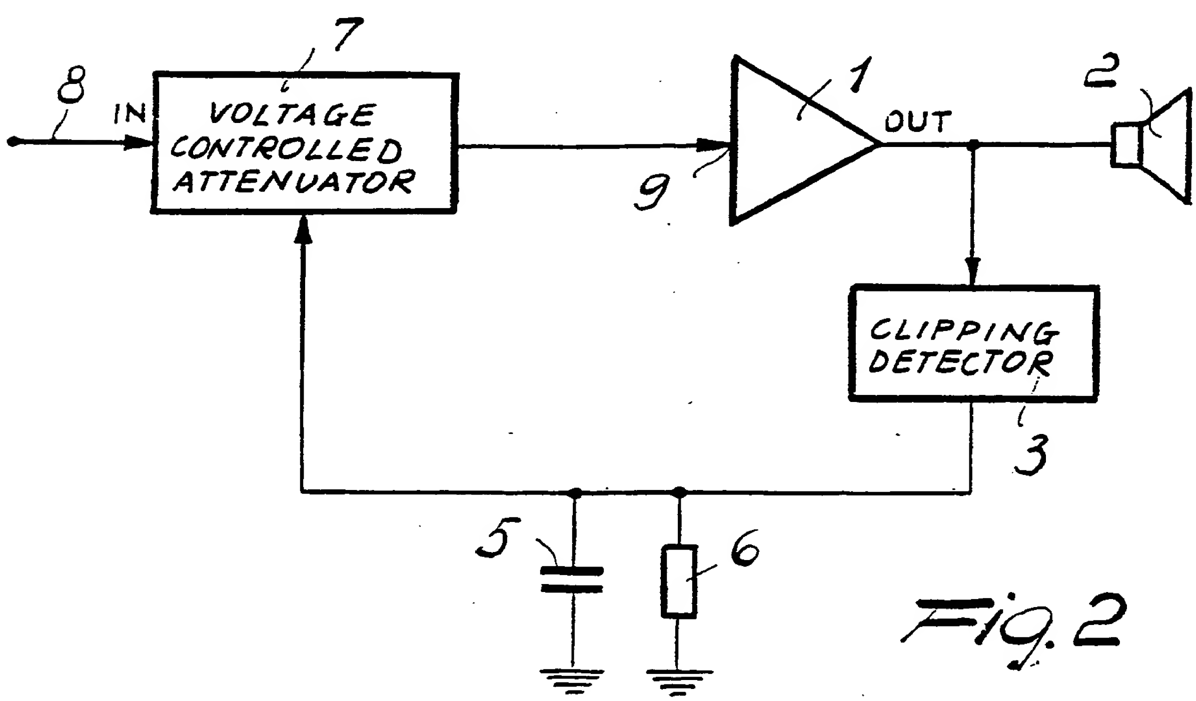

Fig.2

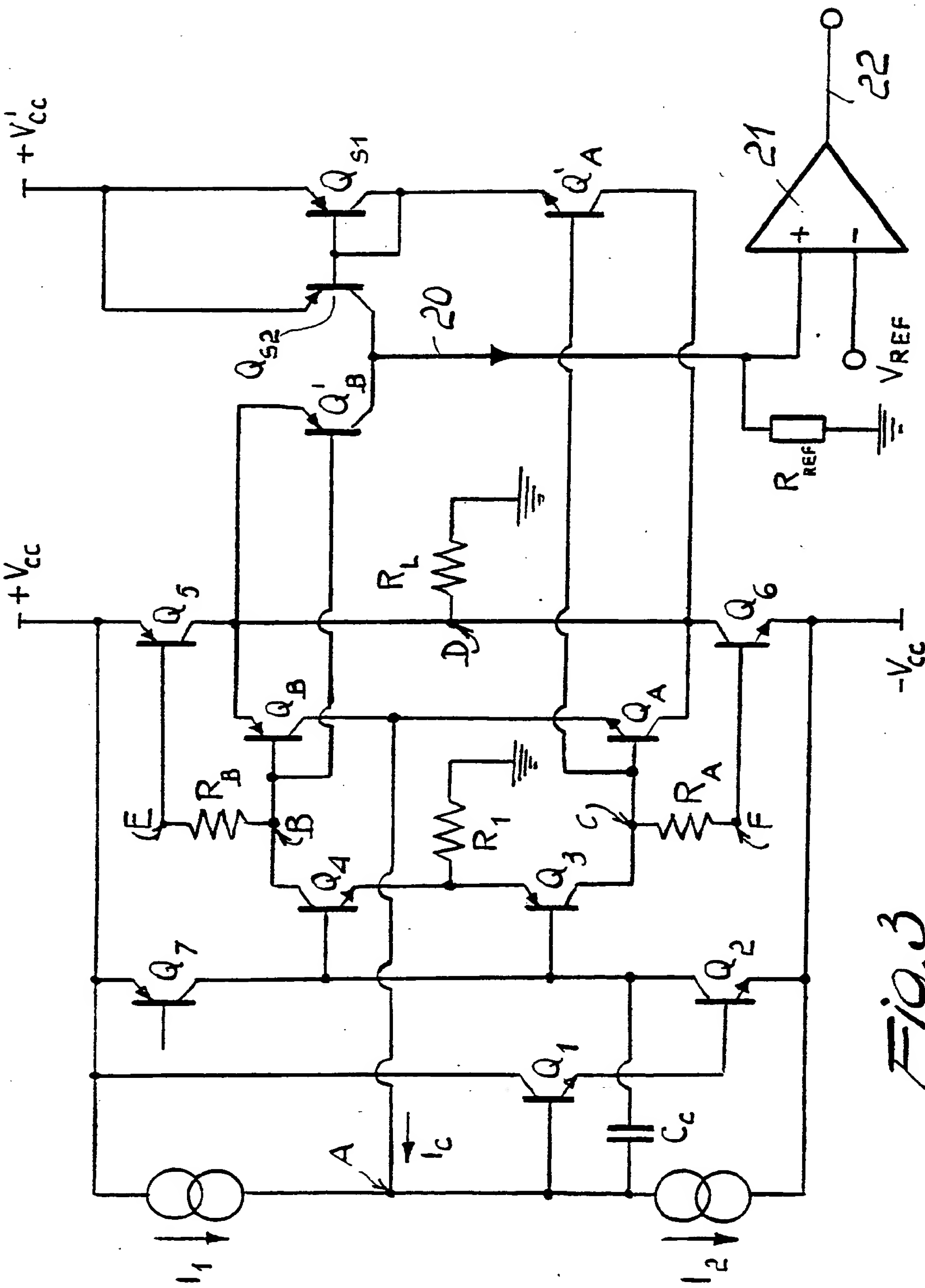
+V'cc
QS1
Q'A
21
22
+
-
QS2
20
Q'B
VREF
RREF
+Vcc
Q5
RL
D
Q6
-Vcc
QB
QA
E
RB
B
R1
C
RA
F
Q4
Q3
Q7
Q2
Q1
A
Ic
Cc
I1
I2

Fig.3

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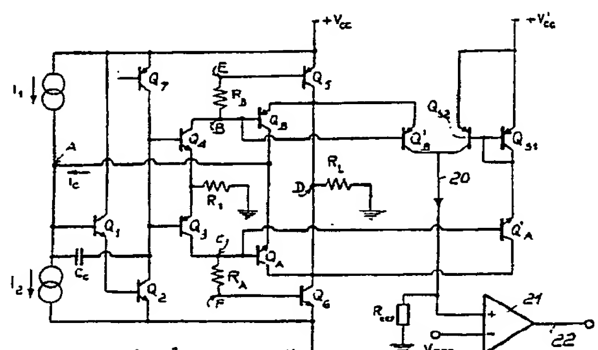

FIG.3

EP 0 295 497 A3

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EUROPEAN SEARCH REPORT

Application Number

EP 88 10 8772

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	GB-A-2 047 032 (TOKYO SHIBAURA DENKI K.K.) * Figures 1,3; page 1, line 42 - page 5, line 37 *	1	H 03 G 3/20 H 03 F 1/32
A	US-A-4 048 573 (R. EVANS) * Figure 1 *	1,3	
P,A	IEEE JOURNAL OF SOLID-STATE CIRCUITS, vol. 23, no. 3, June 1988, pages 794-801, IEEE, New York, NY, US; E. SEEVINCK et al.: "A low-distortion output stage with improved stability for monolithic power amplifiers" * Figures 3,7 *	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

H 03 F
H 03 G

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	08-05-1990	DECONINCK E.F.V.

CATEGORY OF CITED DOCUMENTS

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